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Synanthropy of Sarcophagidae (Diptera) in southeastern Brazil

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Abstract
Sarcophagidae (Diptera) are potential vectors of several pathogens. They are also very important in forensic entomology, providing basic information on the circumstances of death. The objective of this study was to determine the synanthropic index of adult Sarcophagidae collected in Rio Claro, state of São Paulo, southeastern Brazil. Sampling occurred between September 2009 and August 2010. Traps baited with sardines, beef liver, or minced meat were set for five consecutive days per month in three distinct ecological areas representing urban, rural, and forest environments. A total of 440 specimens of sarcophagids were collected. The most abundant species was *Peckia (Sarcodexia) lambens* (Wiedemann), followed by *Oxysarcodexia thornax* (Walker), *Peckia (Euboettcheria) collusor* (Curran & Walley), *Peckia* (*Euboettcheria*) sp., and *Peckia* (*Pattonella*) *intermutans* (Walker). The only species with positive synanthropic index values were *O. thornax* and *P.* (*S.*) *lambens*, which demonstrated a greater preference for inhabited areas. *Peckia* (*Euboettcheria*) *florencioi* (Prado & Fonseca), *P.* (*P.*) *intermutans*, and *Peckia* (*Euboettcheria*) *australis* (Townsend) were only found in the forested area, which demonstrates their importance in forensic entomology because of their preference for a particular type of environment. The greatest number of sarcophagids was found in the forest environment; however, only the forest and rural areas were significantly different in Sarcophagidae abundance.

Introduction

Synanthropic flies have adapted to environmental changes caused by humans and have great medical and sanitary importance (Greenberg 1971, Axtell 1986). Muscoid flies probably developed an association with humans at the beginning of the evolutionary journey of our hominid ancestors, taking advantage of food debris deposits, animal carcasses, and feces; with animal domestication, several species of coprophagous and sarcosaprophagous flies were also associated with humans (Prado 2003).

Nuorteva (1963) described synanthropic flies as species with the ability to utilize favorable conditions created by humans, and he created an index that is used when comparing the quantitative data of a given species in three distinct ecological zones: urban, rural, and forest areas. From this index, the degree to which a species is associated with humans and their modified environments can be inferred.

Immature and adult Sarcophagidae flies feed on several substrates, e.g., corpses, urban waste, and feces; consequently, they become potential vectors of several pathogens (Greenberg 1971). Because they are involved in cadaveric decomposition, this family is also very important in forensic entomology, providing basic information on the circumstances of death (Souza & Linhares 1997, Oliveira-Costa 2003).

The objectives of this study were to (1) elucidate sarcophagid species distribution, (2) investigate possible seasonal variations in their occurrence, (3) determine the synanthropic index of the commonest species, and (4) determine whether different sarcophagids exhibit preferences for a particular location or a certain bait.

Material and Methods

Sample sites

The municipality of Rio Claro (22°24′53.648″S, 47°33′54.502″W) is located in the center-east region of the state of São Paulo, southeastern Brazil, and covers an area of 499.9 km^2, which includes rural, urban, and forest environments and the Assistência, Ajapi, Batovi, Ferraz, and Itapé districts. The municipality has a predominantly tropical climate, with two well-defined seasons. The wet season occurs from October to March (1200-mm rainfall in 55–60 days) and the dry season from April to September (180–200-mm rainfall in 15–20 days) (Troppmair 1978).

The present study was conducted in three different environments in the municipality: rural, forest, and urban areas. The rural area was the property of a soybean and corn producer (22°20′14.141″S, 47°32′46.729″W). The forest area was the Edmundo Navarro de Andrade State Forest (22°25′10.624″S, 47°3′17.831″W), which covers 2.230 ha. The natural vegetation consists of Cerrado and semideciduous forest, and the dominant vegetation consists of several *Eucalyptus* spp. (Castellano *et al* 2013). The urban area was the Santana campus of the Univ Estadual Paulista at Rio Claro, São Paulo state (22°23′58.326″S, 47°34′19.518″W), which is a wooded area that has been occupied by humans for several decades and is surrounded by residential properties.

Collection procedure

Specimens were collected using traps modified from Ferreira (1978), which were made from 2-L plastic bottles that had been cut in half. The bottoms of the bottles were covered with black paint, and the upper halves remained transparent and supported a collection bag to hold the insects after being attracted to the bait.

Sardines, minced meat, or beef liver were used as baits. In each trap, 100 g of bait was placed and was not changed until the end of each collection. We placed three traps at each sampling site, each containing one type of bait. The traps were hung in trees approximately 1.5 m above the ground and spaced equally at approximately 13 m.

The traps were open for five consecutive days, and samples were collected every 24 h after the second day by withdrawing the collection bag; trapped insects were fixed in 70% ethanol for later species identification. The traps were reassembled after the collection procedure. Monthly collections were performed between September 2009 and August 2010. The specimens were identified based on the dichotomous keys of Carvalho & Mello-Patiu (2008).

Data analysis

Friedman's chi-square test was used to statistically compare the Sarcophagidae groups in the three environments. If a significant difference was found between the groups, multiple comparisons were made between each pair. Statistical procedures were performed according to the recommendations of Siegel & Castellan (1988), including between seasons, using the R Development Core Team (2011) program.

Similarities among the baits in each environment were calculated using the Bray & Curtis (1957) index, which is based on distances calculated from the module of differences between the sample densities of each species (Nering & Von Zuben 2010).

We also calculated the synanthropic index (Nuorteva 1963) to ascertain which was the most common species ($n \geq 15$), using the following formula:

$$\mathrm{IS} = \frac{2a + b - 2c}{2}$$

where

- a the percentage of a given species in urban area relative to the percentage of the same species in rural and forest areas
- b the percentage of species in rural areas, and
- c the percentage of species in forest areas.

Results

A total of 440 Sarcophagidae specimens were collected. The most abundant species was *Peckia (Sarcodexia) lambens* (Wiedemann) with 18.2%, followed by *Oxysarcodexia thornax* (Walker), *Peckia (Euboettcheria) collusor* (Curran & Walley), and *Peckia (Euboettcheria)* sp., with abundances of 17.9, 12.7, and 10.4%, respectively. Other species or morphotypes were found at low percentages (Online Supplementary Material - Table S1). Most of the Sarcophagidae were collected in the forest (67.7%), followed by the urban (21.1%), and rural areas (11.1%) (Online Supplementary Material - Table S2). The Friedman test confirmed that the three areas were not equal with respect to abundance ($\mathrm{Fr} = 12.54$, $p = 0.0019$). A pairwise comparison revealed that only forest and rural areas differed significantly from each other ($p < 0.05$). The only species that exhibited positive synanthropic index values were *O. thornax* (+43.59) and *P. (S.) lambens* (+3.085). The values for the other species were negative (Online Supplementary Material - Table S2).

Analyzed together, the three baits attracted significantly different numbers of Sarcophagidae ($\mathrm{Fr} = 13.54$, $p = 0.001$).

Pair-wise comparisons revealed that the number of sarcophagids attracted to sardines, minced meat, and beef liver differed significantly ($p < 0.05$). *Oxysarcodexia angrensis* (Lopes) and *P.* (*Pattonella*) *intermutans* were mainly attracted to beef liver. In contrast, *P.* (*Squamatodes*) *ingens*, *Peckia* (*Euboettcheria*) *anguilla* (Curran & Walley), and *Peckia* (*Euboettcheria*) sp. were more attracted to minced meat. *Peckia* (*S.*) *lambens*, *Oxysarcodexia* sp., *O. thornax*, *Oxysacordexia avuncula* (Lopes), and *P.* (*E.*) *collusor* preferred sardines (Online Supplementary Material - Table S3).

Helicobia aurescens (Townsend), *Bercaea cruentata* (Meigen), and morphotype 2 only ate beef liver. *Peckia (P.) chrysostoma* (Wiedemann), *Oxysacordexia parva* (Lopes), *Peckia (P.) pexata* (Wulp), and morphotype 3 were only captured on minced meat. *Helicobia* sp., *Oxysacordexia diana* (Lopes), *Oxysacordexia admixta* (Lopes), *Oxysacordexia culmiforcipes* (Lopes), *Sarcophaga* (*Lipoptilocnema*) *crispula* (Lopes), *Peckia* sp., and morphotype 1 were only found on traps baited with sardines (Online Supplementary Material - Table S3).

Oxysacordexia paulistanensis (Mattos) was found on all three baits in equal numbers on minced meat and beef liver but fewer on sardines. *Peckia* (*Euboettcheria*) *florencioi* (Prado & Fonseca) was also captured on all three baits in equal abundance on minced meat and sardines but fewer on liver. *Ravinia belforti* (Prado & Fonseca) and *Peckia (Euboettcheria) australis* (Townsend) were only caught on two baits, beef liver or sardines, and minced meat or sardines, respectively, but both species occurred in great numbers on sardines (Online Supplementary Material - Table S4).

There was a significant difference in Sarcophagidae abundance between seasons ($df = 3$, $p = 1.236e\text{-}05$). The greatest number of flies was collected in spring, with 296 (67.3%) specimens, followed by summer with 90 (20.4%), autumn with 36 (8.2%), and winter with 18 (4.1%) (Online Supplementary Material - Table S4).

Peckia (*S.*) *lambens*, *Oxysarcodexia* sp., *O. thornax*, *P. (E.) florencioi*, and *Peckia (Euboettcheria)* sp. were present in all seasons. *Oxysacordexia admixta* (Lopes), *P. (E.) australis*, *P.* (*P.*) *chrysostoma*, *O. parva*, *S.* (*L.*) *crispula*, *Peckia* sp., *P.* (*P.*) *pexata*, morphotype 1, morphotype 3, *O. culmiforcipes*, *O. angrensis*, and *H. aurescens* were collected only in the spring. *Helicobia* sp., *B. cruentata*, and morphotype 2 were found only in the summer, and *O. diana* only in the autumn. No species was collected only in the winter (Online Supplementary Material - Table S4). Urban and rural areas had the lowest Bray–Curtis index value (0.37062937) (Table 1) and the same occurred with minced meat and sardines in urban and forest areas (0.5641; 0.2522) (Table 2).

Table 1 Bray–Curtis index values used to compare species composition in the collection locations.

Bray–Curtis index	
Forest/urban	0.45116279
Forest/rural	0.676923076
Urban/rural	0.37062937

Discussion

Peckia (*P.*) *intermutans*, *P.* (*E.*) *australis*, and *P.* (*E.*) *florencioi* only occurred in the forest environment and are highly asynanthropic because they were not present in environments modified by humans; similar results were obtained by Linhares (1979) for all three species and by Dias *et al* (1984) for the latter species. One explanation for this is that urban and rural areas do not contain a wide variety of substrates that serve as food and/or oviposition sites, unlike forested areas.

Because sarcophagid species choose a specific type of environment, they are important in forensic entomology for the determination of the original scene of the crime in the case of body displacements. *Peckia* (*E.*) *australis* has been found colonizing decaying animal carcasses (Monteiro-Filho & Penereiro 1987, Salviano *et al* 1996, Carvalho & Linhares 2001). Salviano *et al* (1996) stressed the importance of *P.* (*P.*) *intermutans* in criminal investigations in the state of Rio de Janeiro, Brazil, which is also considered indicative of IPM in the state of São Paulo, Brazil (Souza & Linhares 1997, Carvalho *et al* 2000, Oliveira-Costa *et al* 2001). Furthermore, it is noteworthy that *P.* (*P.*) *intermutans* has been found on human corpses in Brazil (Barros *et al* 2008).

Peckia (*E.) anguilla*, *P.* (*S.*) *ingens*, and *P.* (*S.*) *lambens* occurred more frequently in the forested area than in the other areas, as observed by Linhares (1979). According to Linhares (1979) synanthropic index values, the first two species were entirely absent in environments inhabited by humans, and the latter species were mainly found away from human settlements. The only species that exhibited a preference for areas inhabited by humans was *O. thornax*,

Table 2 Bray–Curtis index values obtained with different baits in the three collection locations.

		Minced meat	Sardine
Forest	Liver	0.5351	0.4972
	Minced meat	–	0.2522
Rural	Liver	0.6	0.7949
	Minced meat	–	0.6956
Urban	Liver	0.5882	0.6351
	Minced meat	–	0.5641

unlike the findings of Ferreira (1979) and Dias *et al* (1984). The urban environment has unique characteristics, e.g., waste accumulation, which this species is probably attracted to for food. It is also important in forensic entomology, because it has been found on human corpses in Brazil (Barros *et al* 2008). *O. avuncula* was not found in the urban area, but was common in the forest area. Dias *et al* (1984) observed that this species is completely absent in areas inhabited by humans, corroborating the results of the present study. *Ravinia belforti* was only absent in the forest. This corroborates the results of Linhares (1981) and Dias *et al* (1984), who observed that this species has a preference for areas inhabited by humans.

The forest was the preferred environment of the Sarcophagidae. One possible explanation for this is that although the forest is dominated by *Eucalyptus* species, areas with savannah vegetation contain a great diversity of insects and vertebrates, the carcasses of which serve as a substrate for flesh flies. Furthermore, because the forest has been conserved for several years, there are many large trees, which have resulted in a relatively cool environment in comparison to the other two habitats studied, allowing the occurrence of species that prefer low temperatures (Souza & Zuben 2012).

Sardines attracted several sarcophagid species and have been the most popular bait in population surveys of muscoid flies (e.g., Ferreira 1978, Linhares 1981, D'almeida & Lopes 1983, Carraro & Milward-de-Azevedo 1999, Marinho *et al* 2003), even in forests (Lopes 1973, D'almeida & Lopes 1983). In a study conducted in Saudi Arabia, it was found that fish bait was preferred by two of the three fly species collected (Abouzied 2010). Furthermore, Yepes-Gaurisas *et al* (2013) reported that using fish to attract Sarcophagidae is highly effective. Minced meat and sardines in urban and forest areas were the most similar in attracting species, suggesting that future surveys of Sarcophagidae should avoid only using these baits in these environments. In rural areas, the same occurred with minced meat.

The Bray–Curtis index revealed that the rural and urban areas were similar in species composition. This may be due to anthropic modifications attracting species that are adapted to these environments. Although the sarcophagid family is distributed worldwide, its diversity is remarkably concentrated in nearby Ecuador regions (Pape 1996). In the present study, significantly more Sarcophagidae specimens were collected during the warmer seasons, probably because they prefer high temperatures.

The results of the present study suggest the need for additional surveys to better understand the association of the species studied with different biotic and abiotic factors and to understand possible future changes in their synanthropic index values.

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